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CHANGE IN RESPIRATION WITH INCREASING HYPERCAPNIA

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CHANGE IN RESPIRATION WITH INCREASING HYPERCAPNIA

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ABSTRACT: The article presents an analysis of the changes in the indices of external respiration in man with concentrations of carbon dioxide increasing at various rates in the inspired air. It was found that as the rate of accumulation of CO_2 in the inspired air decreased, the compensatory mechanisms of external respiration were able to adapt more fully and the individual was able to better tolerate an increase of up to 6% in the concentration of carbon dioxide.

Changes in respiration at increased and high concentrations of CO_2 in the /1820* inspired air have been studied by a number of authors [1, 3-5]. However, the dynamics of the development of compensatory reactions in external respiration with increasing hypercapnia has been insufficiently studied [2]. This problem is of definite theoretical and practical interest. In the course of his activity, especially in emergency situations, man frequently encounters the influence of slowly increasing concentrations of carbon dioxide in the inspired air.

The purpose of the current studies was to investigate the state of the function of the human organism, especially the functions of external respiration, as a function of the rate of increase of CO_2 concentration in the atmosphere surrounding the individual.

Method

One hundred and ten experiments of varying duration involving healthy young men aged 19 to 25 were organized. The rate of increase of CO_2 in the surrounding atmosphere was 0.08-0.05 and 0.01% per minute. In other words, the concentration of CO_2 in the inspired air was on the order of 6% after 1, 2 and 5

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*Numbers in the margin indicate pagination in the foreign text.

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hours of the experiment. The check on the content of CO_2 was performed with the GEUK-21 gas analyzer, while the O_2 was measured by the "Oksitest" gas analyzer. In all of the experiments, the O_2 content in the inspired air was normal (21%).

Physiological, psychological and biochemical methods of investigation were used to characterize the general state of the human organism and its mental working capacity. The function of the external respiration was evaluated by the frequency and depth of breathing, pulmonary ventilation and composition of alveolar air. The results of the studies was subjected to subsequent statistical analysis.

Results of the Study and Their Evaluation

Phylo- and ontogenesis indicate that the resistance of adult animals and man to carbon dioxide is achieved as the result of accommodative reactions, mainly involving external respiration [6]. The initial reaction of the organism to a rise in CO_2 content in the inspired air is a pronounced increase in pulmonary ventilation due mainly to deepening of respiration. Figure 1 shows the changes in the principal indices of external respiration as a function of the level of CO_2 in the inspired air. The increase in pulmonary ventilation with gradually increasing CO_2 content in the inspired air was due mainly to /1821 the increase in depth of respiration, which is a positive sign and constitutes a compensatory reaction aimed at retention of stability of the composition of the alveolar air.

The results of the studies showed that when the CO_2 content in the inspired air reaches 2.5-3.0%, the P_{ACO_2} increases only by 2 to 3 mm Hg. However, when the CO_2 in the inspired air rises above 3%, the increased pulmonary ventilation is unable to retain a normal P_{ACO_2} and hypercapnia develops in the organism. With 5% CO_2 in the inspired air, P_{ACO_2} increases to 8 to 10 mm Hg.

The magnitude and the nature of the changes in the external respiratory characteristics depend on the rate of increase of CO_2 content in the inspired air. Figure 2 shows the changes in pulmonary ventilation as a function of

the rate of increase of CO_2 in the inspired air. It is evident from the figure that at a high rate of increase of CO_2 in the inspired air (0.08% per minute), pulmonary ventilation increases very rapidly, reaching 200% of the initial value at the end of the first hour; P_{ACO_2} increases by 10 to 12 mm Hg at the same time. When the rate of increase of CO_2 in the inspired air is 0.01% per minute, pulmonary ventilation increases by only 10 to 15% after one hour while it amounts to 240 to 250% of the initial level after four hours. An insignificant increase in P_{ACO_2} begins to make itself felt only after the third hour.

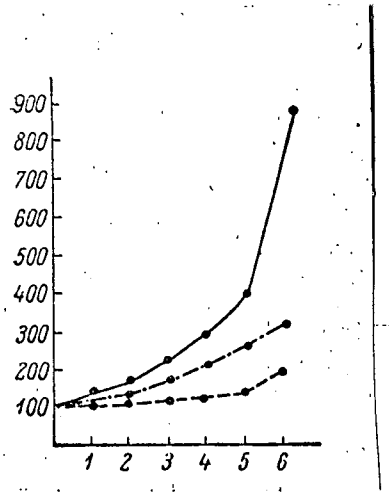

Figure 1. Changes in Principal Indices of External Respiration as a Function of CO_2 Content in Inspired Air. Ordinate: Percent of change in function of external respiration for pulmonary ventilation (solid curve), depth of respiration (dot-dash curve) and respiratory frequency (dotted curve). Abscissa: Percent of CO_2 content in inspired air.

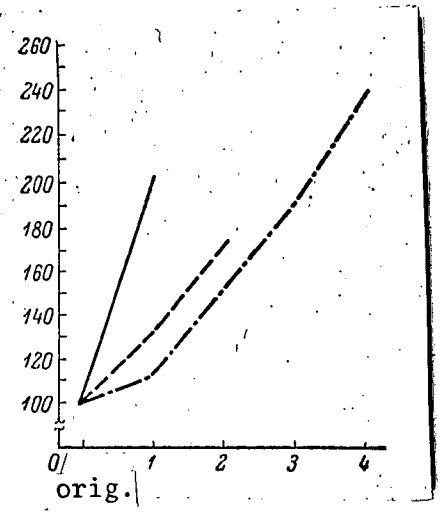

Figure 2. Pulmonary Ventilation vs. Rate of Increase of CO_2 Content in Inspired Air. Ordinate: Pulmonary ventilation, percent of original; Abscissa: Time in hours. Solid curve, increase in CO_2 content in inspired air at the rate of 0.08% per minute; Dotted curve, 0.05% per minute; Dot-dash curve, 0.01% per minute.

Hence, with a slow increase of the concentration of CO_2 in the inspired air to 3%, the P_{ACO_2} remains practically constant, and the state of hypercapnia

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practically does not develop in the human organism. The functional changes which are usually observed in this context, involving respiration, cardiovascular, central nervous and other systems and organs are probably of a reflex nature.

In conclusion, we should point that the results of our studies have shown the following relationship: the lower the rate of increase of carbon dioxide in the inspired air, the more gradual, full and complete will be the compensatory mechanisms of external respiration. This is indicated by the less pronounced functional changes in the organism of man with a rise in the CO_2 content in the inspired air to 6% at the rate of 0.05 percent per minute and especially 0.01% per minute in comparison with the changes observed when the rate of increase of CO_2 content is 0.08% per minute. /1822

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